

## Research Article

### Design of Farm Environmental Monitoring System Based on the Internet of Things

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**Abstract:** The aim of the study is to design the farm environmental monitoring system based on the Internet of Things (IoT) and to realize the automate management of agriculture and the implementation of precision production. The system is made up of three layers which are sensor layer, transmission layer and application layer, respectively. The modular structure is adopted to develop coordinator node and router node which have flexible structures and strong versatility, the node connects with sensors through standard analog interface, on the basis of which, high reliability, flexible Wireless Sensor Network (WSN) is built, the WSN can perceive environment information for greenhouse tomato growth in a real time way and transmit the data to the remote server management system reliably. Field experiments show that WSN is stable, reliable and provides basis for the scientific management of farm.

**Keywords:** Internet of Things (IoT), precise agriculture, wireless sensor networks

## INTRODUCTION

Precision agriculture is the trend of the world agriculture development. For precision agriculture, the soil and crop management practices are fine and accurately adjusted according to the specific conditions of each field of the operating unit and various agricultural inputs are used with a maximum (Vermesan *et al.*, 2009; Harmant *et al.*, 2005). It is helpful to obtain the highest yield per unit area and the maximum economic benefit and protect agricultural ecological environment. This is not only the requirements of sustainable development, but also the manifestation of social progress. The monitoring and control of the farmland environment is the key technique to support precision agriculture. Real-time, convenient and efficient acquisition of agricultural environmental parameters is an important foundation to achieve precision agriculture. The wired networking mode or the artificial field gathering method is adopted in the traditional farmland environmental monitoring system, but both of them have some limitations. The mode of wired networking can cause the confusion of cable. In addition, the apparatuses need to be adjusted accordingly and the cables connected of devices need to be rearranged, when the crop is changed. Therefore, the investment cost and the difficulty of installation and maintenance increase and the growth of crop is affected. There are some limitations for artificial field-

gathering, such as large amount of manpower and resources, limited amount of data obtained, inevitable measurement error.

The emerging IoT technique provides a new method for access to farmland information technique. IoT is the expansion of communication network and internet application, which is a technique to sense the physical world by sensing technology and the intelligent devices through the interconnection, calculation, processing and knowledge mining to achieve the information exchange and seamless links among the persons and objects or among the things and to achieve real-time control of the physical world, accurate management and scientific decision-making (Morais *et al.*, 2008; Wei *et al.*, 2010; Zang *et al.*, 2007; Changchun *et al.*, 2007).

Accordingly, the measuring control system based on the IoT is designed and established. In this system, the wireless sensor nodes are deployed in a monitoring area and a self-organizing network system is formed through wireless communication. The information of the perceived object is sent to the remote server through the cooperative sensing, collecting and processing the information in the network coverage area. Researchers can remotely monitor farmland in real time at the master control room and make the right decisions based on the information collected to meet the requirements of the precision agriculture-automation, economization and accuracy.

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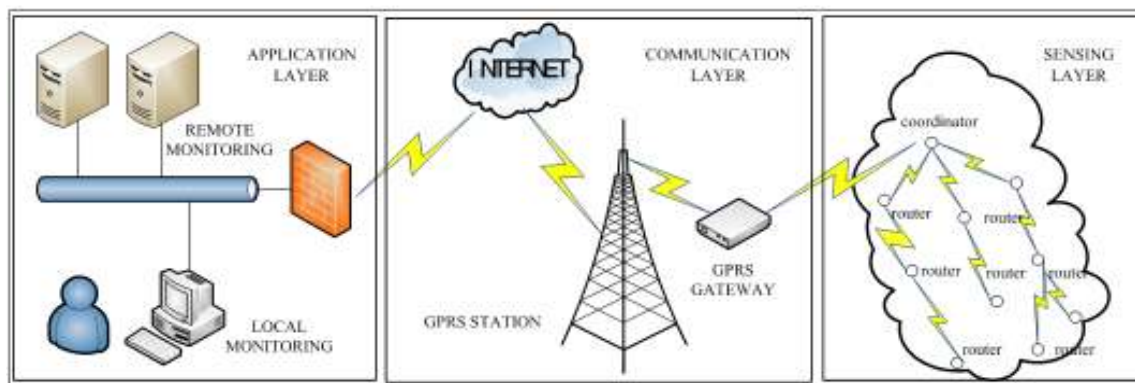


Fig. 1: The architecture of IoT

## MATERIALS AND METHODS

**The measuring control system based on the IoT:** The architecture of accurate measurement and control of farmland irrigation system is shown in Fig. 1, which consists of sensing layer, communication layer and application layer (Lee *et al.*, 2011; Shen *et al.*, 2009; Liu *et al.*, 2008). Three-tier structure of IoT can guarantee the collection, transmission and real-time processing for the farmland environment data. Sensing layer comprises the router and coordinator nodes deployed in the area of the farmland information collection by Zigbee wireless self-organization network. The router and coordinator not only have communication function, but also can collect the information of the environment, such as the air temperature and humidity, light intensity, soil moisture and so on.

Network layer comprises the gateway node, GPRS network and Internet (Liu, 2008; Hwang *et al.*, 2010). The message of the farmland environment parameters can be sent to the monitoring terminal through the network layer. The gateway node includes sink nodes and gateway part. The part of sink node can receive the information from the sensing layer and sends it to the gateway who will pass the information to Internet through GPRS mode.

Application layer is composed by the remote monitoring terminal. When the monitoring terminal join the Internet, the managers can monitor the agricultural information collected at any time and place, do some real-time tracking and analysis on the crop growth status and take appropriate control measures according to the environmental to achieve precise control of water.

**The hardware design of router and coordinator:** The router and coordinator of the sensing layer of IoT are the basic constituent units, which have the function of environment sensing and information transformation and utilize various sensors to achieve the information collection for environment form multi-angle and multi-scale and drip irrigation control. Microprocessor is the core part of the router and coordinator, which is used to

collect the data from sensor and feedback to the remote server. According to the electrical characteristics of the monitor system sensor and the task of the system and considering the system's reliability, maintainability and portability and the harsh work environment requirement, the router and coordinator includes voltage transformation circuit, solenoid valve control circuit, serial port expander circuit, sensor current-voltage signal transformation circuit, ZigBee module and the coordinator has an extra GPRS module than router. The hardware structure of the router and coordinator node is shown in Fig. 2. These nodes are designed using a modular structure with the core of the information perception master-leaf, supplemented by the corresponding function modules.

The router and coordinator are the hardware basis for wireless sensor network. The node microprocessors uses MC9S12XS128 produced in Free scale Semiconductor Company, which is responsible for collecting the 8-channle analog signals and controlling 6-channle water control valve. There are 6 serial ports for each node through expanding the MC9S12XS128 serial port 1 to 6-channel by expansion chip GM8125. Serial port 0 is connected to Zigbee module, which is used to receive and send commands. Serial port 1 is connected to LCD, which is used to display the node information currently collected. Serial port 2 is used to connect to GPS module and display the geography information. As to the coordinator, GPRS module is connected by serial port 4, used to communicate to the remote server.

The node soil temperature and humidity sensor uses PH-SWR-100W produced in Wuhan new Pratt and Whitney CommTech Co., Ltd. LCD display uses serial LCD DMT32240S035\_01WN\_CN produced in Beijing Diwen CommTech Co., Ltd. ZigBee wireless transparent transmission module uses QAZ2000 produced in Hangzhou Qiujie CommTech Co., Ltd. GPS uses GR-87GPS received module produced in Beijing Middle Ground Navistar CommTech Co., Ltd. SY-HGY photosynthesis system produced in Shijiazhuang Shiya CommTech Co., Ltd. is used to mensure photo-synthetically active radiation. The temperature and humidity transducer uses AQ3020Y

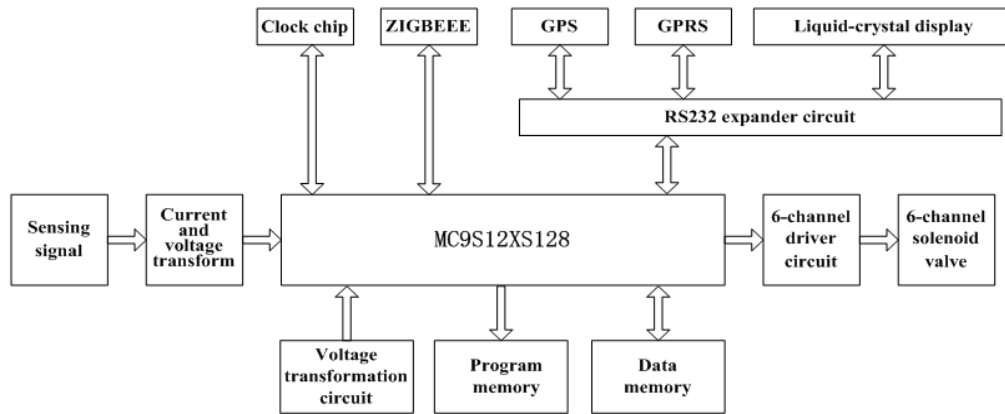


Fig. 2: The hardware structure of the router and coordinator node



Fig. 3: The router



Fig. 4: The coordinator

produced in Guangzhou Lexiang electronic Co., Ltd. GPRS uses HC-GPRS/232/T module produced in Nanjing Huichi Company, erected in which the GPRS transparent transmission specialized server is also used. Therefore, users do not need to ask for their own fixed IP, but can enjoy fixed IP services.

In additional, the node clock circuit is used to control the operating frequency of the entire system. JTAG is considered as the interface for program debugging and downloading. Reset circuit is used to

restore with the unexpected situations of system crash or program runaway. Power supply module is responsible for the energy supply for the entire node. The structure frame of the router and coordinator is respectively shown in Fig. 3 and 4.

**The software design of router and coordinator:** The router nodes and coordinator node can form the ad hoc networks. They perform different functions in transporting information in WSN, where coordinator is the core node. Coordinator node is also the first node that joins the network when ZigBee WSN is created. It receives the command from the remote server by GPRS module and then forwards the command to the destination router node through the relay node via ZigBee module. At the meanwhile, the coordinator node also can receive the acquisition and return data from the router nodes and send them to the remote server by GPRS. The router nodes receive and execute the command from the remote server which forwarded by coordinator nodes or other relay router nodes via ZigBee module and the results would feed back to the coordinator node by the relay router nodes. The coordinator packs the result data and returns them to the remote server by GPRS.

## RESULTS AND DISCUSSION

**Frame format:** According to the different command types which the server sends to coordinator and router node, the information frames and response frames are formulated and their formats are as follows.

**“Addressing frame” and “addressing response frame”:** Addressing Frame from server to coordinator or routers: Addressing Frame Header + Number + Length + Function Number + Frame Tail.

**Addressing response frame from coordinator or routers to server:** Addressing Response Frame Header

+ 00 + 00 + 00 + Network Address (High bytes) + Network Address (Low bytes) + Frame Tail.

Addressing Frame Header: 0xf1h.

Number: 0-0xffh. The number for coordinator is 0. The number for router cannot be 0. The number cannot be duplicated.

Function Number: 0xaaH.

Length: Total bytes of the frame.

Frame Tail: Algebraic addition of the frame.

Addressing Response Frame Header: 0xfdH.

Network Address: The 16-bit address for the addressed node in WSN.

**“Gathering frame” and “gathering response frame”:** Gathering Frame from server to coordinator or routers: Gathering Frame Header + Network Address (High bytes) + Network Address (Low bytes) + Function Number + Frame Tail.

**Gathering response frame from coordinator or routers to server:** Gathering Response Frame Header + 00 h + 00 h + 00 h + Function Bytes + Network Address (High bytes) + Network Address (Low bytes) + Gathering information + Frame Tail.

Gathering and Gathering Response Frame Header: 0xfdH.

Function Bytes: 31H.

**Gathering information:** The information collected by the sensors, totally 5 bytes. The orders are soil temperature, soil moisture, air temperature, air humidity and photosynthetic active radiation.

The other definitions are the same as the above.

**“Control frame” and “control response frame”:**

Control Frame from server to coordinator or routers: Control Frame Header + Network Address (High bytes) + Network Address (Low bytes) + Function Number + Control Byte + Frame Tail.

**Control response frame from coordinator or routers to server:** Control Response Frame Header + Number + 00 + 00 + Function Number + AAH + Frame Tail.

Control and Control Response Frame Header: 0xfdH.

Function Bytes: 32H.

**Control byte:** The open and close instructions of the solenoid valves. In this Byte:

D5: Solenoid valve 1, 0-close, 1-open.

D4: Solenoid valve 2, 0-close, 1-open.

D3: Solenoid valve 3, 0-close, 1-open.

D2: Solenoid valve 4, 0-close, 1-open.

D1: Solenoid valve 5, 0-close, 1-open.

D0: Solenoid valve 6, 0-close, 1-open.

**Main program of coordinator and router:** Before the formation of the ZigBee network, the ZigBee and GPRS module should be put up first. One coordinator node and several router nodes would be configured. The network address for coordinator node is 0000H. And the network addresses for router node 1, router node 2, etc., are 0xfa80 h, 0xfb02 h, etc. The IP addresses for two GPRS modules are configured as: 10.1.46.0 and 10.1.46.1.

The coordinator node and router nodes first initialize the system after power on, then choose the

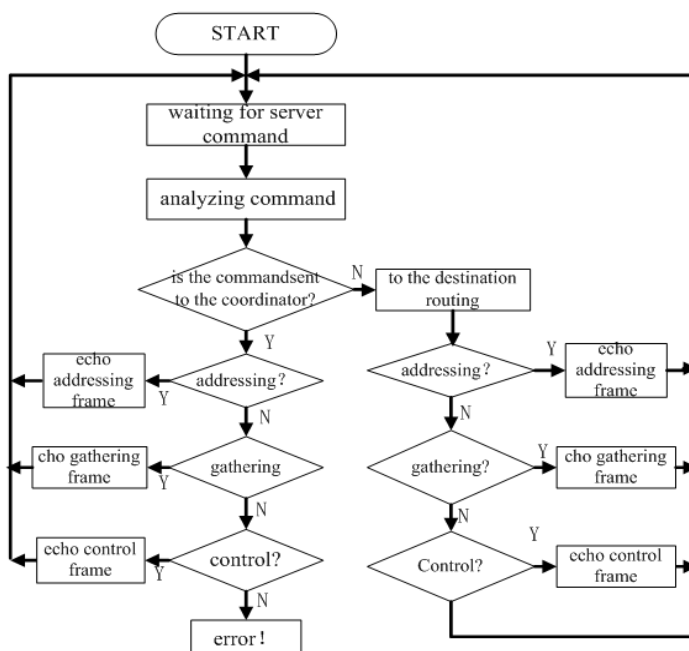


Fig. 5: Flow chart for coordinator

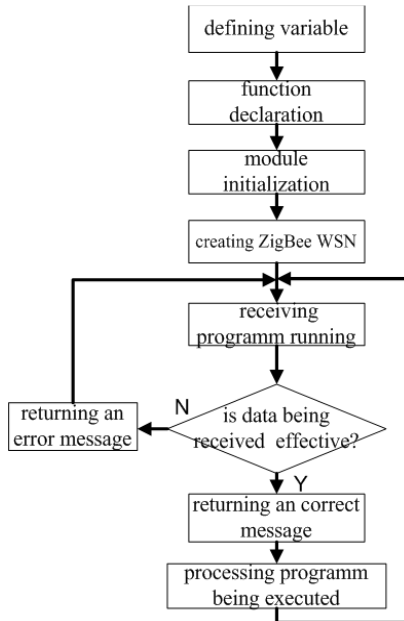


Fig. 6: Flow chart for routers



Fig. 7: Coordinator node



Fig. 8: Router node

channel and join the current ZigBee network, waiting to receive signals. The remote server sends the command frames to the coordinator node and router nodes. The server controls the coordinator and routers in a certain order. First, the server obtains the network addresses of all nodes. Then, the “Gathering” and “control” operations are performed on the nodes every 10 sec and the results would display on the coordinator’s screen. The processes are shown in Fig. 5 and 6.

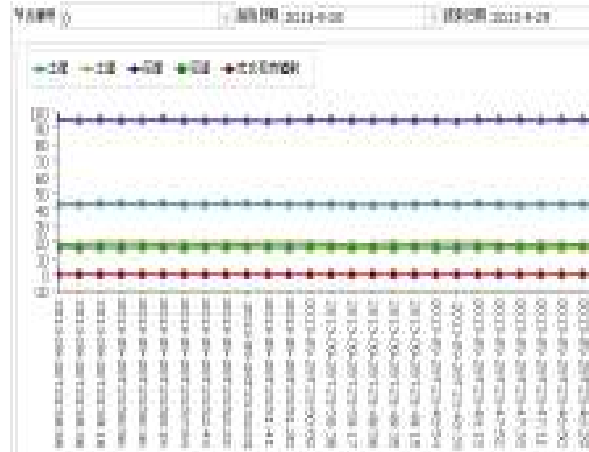


Fig. 9: Monitoring information

**Experiment:** The environmental monitoring system has been applied in Anhui Agricultural University. According to the size of this area, one server, one coordinator node and ten router nodes are used in this experiment, as shown in Fig. 7 and 8. The nodes collect the data such as soil temperature, soil moisture, air temperature, air humidity and photosynthetic active radiation. The monitoring system works well and the data keeps stable and continuous, as shown in Fig. 9. And the data of photosynthetic active radiation is reduced 20 times, so that it can be put in the figure with the temperature and humidity data of soil and air.

## CONCLUSION

To promote the intelligence and automation in the agriculture, it is a trend to apply the IoT technology. The environmental monitoring system based on the IoT can meet the fast, accurate and continuous measurement requirements in the precision agriculture. The farm environmental monitoring system based on IoT is proposed in this study. The system architecture is constructed. Meanwhile, both the hardware and software system for coordinator and routers are designed, integrated with the sensor, embedded system and network communication technology. The results of the experiment show that the new proposed system has the advantages of good in timeliness and more secure in data transmission, with broad application prospect and industry value.

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